Senior Thesis

Identification of Asbestos Minerals in Building Materials of Orton Library

by
Mary Heather Bents
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Approved by:

Michael Barton by R.V.D.
Dr. Michael Barton

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ABSTRACT

Building material from the main stacks of Orton Library was sampled and analyzed for the presence of asbestos minerals. Electron microprobe analysis, X-ray diffraction, and optical microscopy were used to identify minerals in the project samples. Only one of the six known asbestos minerals was found in the building material. Chrysotile was identified in the samples by the optical microscopy method. No estimates regarding the relative percentages of asbestos in the project samples were made.

INTRODUCTION

The purpose of this study was to analyze and identify the minerals in samples of building material from Orton Library, and confirm or dismiss the presence of asbestos minerals. Methods of analysis used include optical microscopy, X-ray diffraction, and electron microprobe.

Owing to the controversial nature of asbestos minerals and related health effects, as well as federal and state regulations that govern the abundances of these minerals in the environment, this study makes no formal assessment of the quantity of asbestos minerals found in the project samples, nor any judgment regarding the safety of the building from which they were taken.

ASBESTOS

Mineralogy

Asbestos is the term used to classify highly fibrous, naturally occurring silicate minerals. This group of minerals includes chrysotile of the serpentine group, and fibrous amphiboles such as crocidolite, amosite, anthophyllite, actinolite, and tremolite. Individual crystals of these minerals are elongate fibers with very small widths, and are generally strong, flexible, heat resistant, and chemically resistant. Asbestos mineral fibers form bundles that share a common axis of elongation. Widths of individual fibers may vary between and within mineral species. Average widths range from 0.05 µm., as in chrysotile, to 0.70 µm., as in anthophyllite (Veblen and Wylie, 1993). Data in Table 1 illustrates the tensile strength and dissolution kinematics (percent weight loss after interval treatment with dilute acid) of some asbestos minerals; data in Table 2 shows optical characteristics and relative flexibility between asbestos minerals.

Chrysotile $Mg_3Si_2O_5(OH)_4$

Chrysotile is the fibrous variety and least abundant polymorph of the serpentine minerals. Also known as "white asbestos", chrysotile is the most common asbestos mineral, once comprising 95% of world asbestos production. It is characterized by narrow, tubular fibers that are often hollow and on the order of 1 cm. in length (Klein and Hurlbut, 1985). Fiber bundles are typically white to light green, and have a silky texture.

Chrysotile has the fastest dissolution kinematics of all asbestos minerals (Veblen and Wylie, 1993). Kane (1993) reports that workers exposed to chrysotile have low levels of fibers in their lungs when examined at autopsy. Chrysotile fibers do not appear to remain in the lungs over time because they fragment or dissolve (Kane, p.351). As dissolution kinematics of asbestos minerals are directly related to their potential health effects, the relatively rapid dissolution of chrysotile suggests a lower risk of harmful health effects than that associated with the amphibole asbestos minerals.

Chrysotile occurs naturally in hydrothermally altered ultrabasic rocks, such as dunites, peridotites, and pyroxenites (Klein, 1993). Chrysotile has been mined from these serpentinized host rocks in Eastern Canada, California, the former U.S.S.R., and South Africa (Veblen and Wylie, 1993).

Crocidolite $Na_2Fe^{+3}_2(Fe^{+2},Mg)_3[Si_8O_{22}](OH)_2$

Crocidolite, also known as "blue asbestos", is the fibrous form of riebeckite. Crocidolite once comprised up to 4% of world asbestos production, but has not been mined since 1966 (Klein and Hurlbut, 1985). This asbestos mineral is characterized by its fibrous habit and blue color which increases in darkness with increasing iron content. Crocidolite displays pleochroism in thin section, from colorless to blue.

In comparison with other asbestos minerals, crocidolite is the most flexible of the amphiboles. Even more importantly, crocidolite's relative dissolution kinematics are slowest overall (Veblen and Wylie, 1993). This characteristic is directly related to the residence time of mineral fibers in body tissue, thus, the potential for harmful health effects. For example, the clearance rates of crocidolite from rodent tissue in asbestos pathological studies have been found to be the slowest of the asbestos minerals. Skinner and Ross (1988) report that chrysotile is cleared from lung tissue most rapidly, and crocidolite is deposited and retained in larger amounts (p.141).

Crocidolite is most commonly found in the Hamersley Range of Western Australia. The deposits were formed by hydrothermal fluids, and are interbedded with Precambrian banded iron formations (Klein, 1993).

Amosite $(Fe^{+2},Mg)_7[Si_8O_{22}](OH)_2$

Amosite, also known as "brown asbestos", is the name applied to fibrous grunerite. The name is derived from the word amosa, an acronym for the company "Asbestos Mines of South Africa" (Klein, 1993). Amosite is a fibrous, silky mineral that occurs in various shades of light brown. Amosite is distinguished macroscopically from chrysotile by its non-curling, "whisker" fibers; and from crocidolite by its color and lack of a pleochroic scheme. Amosite fibers are among the least flexible of amphibole asbestos minerals. The dissolution kinematics of amosite are significantly slower than those of chrysotile, yet are fast relative to the dissolution kinematics of crocidolite (Veblen and Wylie, 1993).

Amosite is largely associated with metamorphosed iron and magnesium-bearing protoliths, and is found in the Eastern Transvaal Province of South Africa (Klein and Hurlbut, 1985).

Anthophyllite $(Mg,Fe^{+2})_7[Si_8O_{22}](OH)_2$

Anthophyllite asbestos is very similar in appearance to amosite, but is characterized by its diagnostic "clove-brown" color. Anthophyllite is a metamorphic mineral of magnesium-rich protoliths of Finland (Veblen and Wylie, 1993).

Tremolite - Actinolite Series
$Ca_2Mg_5[Si_8O_{22}](OH)_2$ - $Ca_2(Mg,Fe^{+2})_5[Si_8O_{22}](OH)_2$

Both tremolite and actinolite occur in a fibrous habit, and are included in the list of regulated asbestos minerals, as decided by the Environmental Protection Agency (A.T.S.D.R., 1990). The fibers of these asbestos minerals are silky, with color ranging from white to green with increased iron content.

Tremolite and actinolite asbestos are confined to calcium-rich metamorphosed rocks, such as dolostone. Both are found in the Northeastern United States (Veblen and Wylie, 1993).

Uses of Asbestos Minerals

Before their regulation by the Federal Government in 1972, asbestos minerals were used in a variety of applications. Figure 1 divides asbestos products into three groups: fiber mixtures (Group I), asbestos composites (Group II), and asbestos textiles (Group III).

Products from Group I were often mixed with water and used as insulating plasters, cement, and sprays. Asbestos products from Group II had the greatest number of applications as building materials, including cement, insulation boards, millboards, reinforced plastics, and vinyl tiles and sheets. These products yielded durable, insulated materials that were also often impermeable to water. Group III asbestos products were used to produce fire-resistant cloth, insulation cloth, friction products such as brake linings and clutch facings, and heat-resistant packing material (W.H.O., 1986, p.38-43).

Table 3 lists examples of asbestos products, with their relative asbestos mineral content and reference to Figure 1.

Identification of Asbestos Minerals: The Orton Library Example

Location and Type of Samples

Six bulk samples were taken from the ceiling above the main stacks on the east side of Orton Library. The samples were removed from the ceiling, roughly 7½ feet above the top of the book stacks on the balcony level. Figure 2 shows the location of the sample area on the Orton Library map.

Samples 1 through 5 were taken from an oval-shaped area, roughly 20 inches in length and 9 inches in width, or 200 square inches. Figure 3 illustrates the order and spacing between the samples. The samples were extracted from a sandy cement layer directly under white surface plaster and paint. All five samples were heterogeneous, containing quartz and pebbles. Also present were paint chips, remnants of plaster, and (visible with the use of a stereoscope) white fibers.

The sixth sample was taken from the lower frieze on the east wall, three book stacks to the right of the first sample area. This last sample was collected directly over the southeast window of Orton Library. The material taken from this location was homogeneous white powder.

Methods of Identification

Common mineralogical identification techniques include optical microscopy (OM), X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), and electron microprobe analysis (Veblen and Wylie, 1993). This study only discusses the use of electron microprobe analysis, XRD, and OM for identification of asbestos minerals in bulk building material.

ELECTRON MICROPROBE ANALYSIS:

The first mineralogical identification technique attempted in this project was the use of the electron microprobe. Fibrous materials from each sample were mounted onto a plate, treated with epoxy, and polished for analysis.

Preliminary analysis indicated that the samples contained too much gypsum to get an accurate reading for any asbestos minerals, both serpentine and amphibole. In an attempt to isolate amphibole minerals, the samples were treated with warm, dilute HCl to dissolve the gypsum.

Samples were again mounted and analyzed. However, the fragile fiber surfaces could not yield accurate analyses, and the fibrous material could not be properly identified with this technique.

The failure of the electron microprobe analysis to correctly identify the fibers in the bulk building materials was not surprising. Even if the fibers were asbestos, this particular technique is not an ideal method in asbestos mineral identification. Veblen and Wylie (1993) note this difficulty: "Analyses from particles and fibers currently cannot achieve the accuracy or precision possible with thick, flat, polished surfaces" (p.125).

X-RAY DIFFRACTION:

The next mineralogical identification technique used to identify asbestos minerals was X-ray diffraction. Only material from Sample 3 was analyzed with this method.

The material was hand-ground into a fine, silt-sized powder. The powder was mixed with acetone and smeared onto a clean glass slide. Once dry, the slide was inserted into the sample chamber of the machine.

The XRD mineral analysis was performed using the Philips XRG-3100 unit. Control setting were as follows: 35 kilovolts, 15 milliamps, 500 counts/second range, scanning speed of 1° per 2-theta min., and the X-ray chart speed of 30 inches/hour.

Four diffraction patterns for Sample 3 were produced; three of which were made from unsieved powder, at varying ranges, and one from a powder that had been sieved through a 0.177 mm. sieve. The sieving was done in an attempt to isolate fine fibrous material. All analyses produced virtually identical patterns. Figure 5 shows the diffraction pattern for unsieved Sample 3 material which ran from 5° to 65° 2-theta.

The pattern for Sample 3 displays an array of peaks, most of which are attributed to quartz and anhydrite. Other peaks were identified as bassanite, feldspars, and micas. Table 4 indicates the probable mineral for each peak.

As with the electron microprobe analysis, the XRD analysis also failed to detect asbestos minerals in the bulk sample. Several factors explain these results. First, the results may indicate a lack of asbestos minerals in the analyzed sample. Another possibility is that the sample contains several minerals, whose diffraction patterns may overlap and obscure each other (Veblen and Wylie, 1993, p.122). This potential explanation is certainly suitable for the analysis of Sample 3, as the XRD pattern reveals several peaks for several different minerals. A last possibility is that the relative amount of any asbestos minerals present is too minute to be detected in the XRD analysis. Other problems that occur with the XRD method of identification include varying peak intensities with preferred orientation and structural disorder. Furthermore, XRD analyses highlight the physical/structural characteristics of a mineral, and it is difficult to distinguish between chemically identical minerals without special sample mounting (Veblen and Wylie, 1993). This problem is an obvious setback in the identification of minerals that are defined by their fibrous habit.

OPTICAL MICROSCOPY:

The final mineralogical identification technique used in this project was optical microscopy. Also known as Polarized Light Microscopy (PLM), this technique is the official method used by professional agencies to correctly identify asbestos minerals (E.P.A., 1985). The advantages in using this method are in the ability to analyze only the fibrous unknowns in bulk samples, as well as the ability to conduct relatively rapid analyses of each sample. Efficient analysis is especially important as a single investigation may involve several sites, each having multiple samples.

The optical properties of chrysotile easily distinguish it from the amphibole asbestos minerals. The refractive indices of chrysotile range from 1.54 to 1.56, although heat-treated fibers may exhibit refractive indices up to 1.60 (Veblen and Wylie, 1993). Other optical characteristics of chrysotile include length-slow fibers, parallel extinction, and low to moderate birefringence.

The identification of amphibole asbestos minerals by OM is possible, yet often is insufficient in differentiating between the various minerals. This problem is especially common owing to chemical substitution, alteration, and structural disorder in the mineral species. Optical properties of minerals often overlap in these circumstances, and correct identification may not be possible without a chemical analysis. Also, if the fibers are not wide enough to obtain interference figures, proper identification can be further hindered (Veblen and Wylie, 1993).

Amphibole asbestos minerals generally have higher refractive indices, ranging from 1.60 to 1.80; have moderate birefringence; and with the exception of crocidolite, lack pleochroism and are length slow. Table 1 lists the refractive indices of all asbestos minerals.

All samples that were collected in this project were analyzed by OM. Oil mount slides of sieved samples (sieved through a 0.177 mm. sieve) were prepared using 1.58 refractive index oil. Recall from previous discussion that samples were sieved to try and isolate fine fibrous material. The 1.58 refractive-index oil was selected because 1.58 is the refractive index of anhydrite, is mid-range between both categories of asbestos minerals, and if present, asbestos fibers would have high relief for easy visibility. However, none of the sieved samples had any trace of asbestos fibers. Only fine quartz crystals, anhydrite needles, and cellulose fibers were present in these oil mounts.

Oil mounts of unsieved samples were also prepared with 1.58 oil. In addition to quartz, anhydrite, biotite, and opaque unknowns, the oil mounts from Samples 3 and 5 contained fibers having the same optical properties of chrysotile. Fibers were then extracted from these two samples, using a stereoscope and tweezers. New oil mounts of these fibers were prepared with 1.55 oil. This oil was selected to confirm the identification of chrysotile asbestos.

Samples 3 and 5 were confirmed to contain chrysotile asbestos with an approximate refractive index of 1.55. The fibers were grouped into curly bundles, often intertwined and sticking to other particles. Figures 6 and 7 illustrate chrysotile fibers from Samples 3 and 5, respectively.

Even with the positive identification of chrysotile asbestos in Sample 3 and 5, no quantitative estimates could be made, owing to the prior treatment of the sample with acid. Not enough of the asbestos was present to be detected by either XRD or electron microprobe analysis. Other minerals may have masked the presence of asbestos in the samples. Regardless of the possibilities, the treatment of the samples prohibited any assessment of relative asbestos percentages in the samples for this study.

Health Issues and Asbestos Products

The motivating factor behind this study and other attempts to identify asbestos minerals in building materials is the health hazards associated with exposure to fibrous minerals.

The exposure to asbestos minerals has been connected with several diseases. Among these are: asbestosis, pleural plaques and effusions, diffuse malignant mesotheliomas, and lung cancer (Kane, 1993, p.348). The discovery of the relationship between these diseases and asbestos exposure occurred early in the twentieth century, after extensive mining of asbestos minerals for commercial use had already been established.

Characteristics of Asbestos-related Diseases

ASBESTOSIS:

Asbestosis characterized by "diffuse bilateral scarring or fibrosis of the lungs" (Kane, 1993, p.352). Patients with this condition exhibit shortness of breath with exercise, and often develop a dry cough. Scarring of the lungs can be seen on chest X-rays, and are recognized as "linear and nodule densities predominantly involving the lower lobes of both lungs" (Kane, 1993, p.352). The disease is associated with prolonged exposure to asbestos minerals, and continues to develop beyond the period of exposure. Individuals with this condition are at a higher risk for developing lung cancer.

LUNG CANCER:

Exposure to asbestos minerals, individually, or coupled with a history of smoking, has been linked to the development of lung cancer. Lung tumors form from epithelial cells that have been disturbed and mutated by carcinogenic particles. The injured epithelial cells grow into large masses in the bronchi and bronchioles of the lungs. These masses can be detected with a chest X-ray. Other symptoms include persistent coughing, pneumonia, weight loss, and anemia. Cancerous tumors may spread from the lung to other organs of the body, yielding other symptoms that may not be suggestive of the original respiratory disease (Kane, 1993).

PLEURAL PLAQUES AND EFFUSIONS:

The inhalation of asbestos fibers has also been connected with the development of fibrotic scarring of mesothelial cells lining the pleural cavity around the lungs. This condition can result in different symptoms of varying medical concern. Scarring of pleural tissues often are calcified, causing plaques, and can interfere with the functioning of the lungs. Accumulation of fluid in the pleural cavity, called pleural effusions, is also another reaction to the exposure of mesothelial cells to asbestos fibers. Individuals with pleural effusions may report chest pain, problematic lung function, or no symptoms at all (Kane, 1993).

DIFFUSE MALIGNANT MESOTHELIOMA:

The rarest and most serious pleural reaction to asbestos exposure is diffuse malignant mesothelioma. This disease is characterized by the development of a tumor that grew from mesothelial cells in the pleural cavity, and is most commonly associated with exposure to amphibole asbestos. Tumors of this type have also been known to persist in the pericardial sac or peritoneal lining of the abdominal cavity, and are rarely treatable. Patients complain of weight loss, chest pain, and difficulty breathing (Kane, 1993, p.354).

Epidemiological Studies

Initially described as "miner's sickness", the above respiratory ailments were the focus of study in occupational epidemiological studies of the 1950's and 1960's. Four different methods of occupational epidemiological studies were conducted to investigate the association between the development of respiratory diseases and exposure to asbestos minerals. These methods include: cohort studies, case studies, case control studies, and case series.

COHORT STUDIES:

Cohort studies record the "incidence of disease...in a large group of individuals with similar occupations or other characteristics [over time]" (Kane, 1993). Cohort studies have established the different levels of risk between amphibole and chrysotile asbestos. These studies have determined that the risk of developing diffuse malignant mesothelioma is higher with exposure to amphibole asbestos than with chrysotile. In addition to these findings, the studies found a long, latent period in the progression of the disease, as well as more common incidence of it in certain industries, including shipbuilding, insulation, and assembly of gas masks (Kane, 1993, p.350).

CASE STUDIES:

Case studies review the health, occupational, and behavioral histories of diseased individuals. In addition to smoking, asbestos exposure has been cited in the histories of individuals with respiratory diseases often enough to be considered a contributing risk factor.

CASE CONTROL STUDIES:

Case control studies involve the comparison of two groups of individuals and their relative histories. One group in the study is comprised of disease-bearing individuals, while the other group is assembled with disease-free people. This type of study eliminates the confusion between effects of other contributing factors (such as smoking) and those of asbestos exposure. Results from this method of epidemiological study also suggest that health hazards are higher with exposure to amphibole asbestos in relation to chrysotile exposure.

Kane (1993) cites an example in which members of both the disease-bearing and disease-free control groups worked in manufacturing plants for asbestos friction products. Ten individuals were reported to have malignant mesothelioma, and comprised the total disease-bearing group. Other disease-free workers were matched with members of the disease-bearing group in terms of sex, age, height, weight, duration of employment, etc., and were used to assemble the disease-free control group in the study. It was found that when compared with their disease-free counterparts, the histories of the disease-bearing individuals had a common factor, i.e., exposure to amphibole asbestos. The majority of the disease-bearing individuals had been exposed to amphibole asbestos for a significant length of time in the duration of their employment. Conversely, the disease-free group had only a few members with histories of amphibole asbestos exposure. Most of the disease-free group had worked only with chrysotile. The findings in this method of investigation strongly suggest the connection between amphibole asbestos and the development of diffuse malignant mesothelioma (Kane, 1993, p.350).

CASE SERIES:

The case series method of epidemiological study involves the connection of several cases of a rare disease to a common exposure. Kane (1993) cites a study of this type in which several cases of diffuse malignant mesthelioma were reported in a localized South African area. Upon investigation of the patients' histories and the area in which they lived and worked, it was noted that nearly all patients lived or worked in or around a functioning crocidolite mine in the region. The development of the rare disease in these patients essentially demonstrates a direct relationship between its progression and the exposure to amphibole asbestos.

Conclusions based on these epidemiological studies and other animal-response experiments have established the link between asbestos exposure and respiratory diseases. The confirmation of the health risks has largely shaped modern concerns regarding environmental exposure to asbestos, as well as the regulatory policies that aim to calm these concerns.

Current Policies and Regulations

Asbestos is currently under regulation by several federal agencies. The two agencies that are primarily responsible for establishing asbestos regulations are the Environmental Protection Agency (E.P.A.) and the Occupational Safety and Health Administration (O.S.H.A.). These agencies aim to minimize asbestos exposure in the workplace, minimize emissions during disposal of asbestos-containing materials(ACM), control the amounts of ACM in schools and homes, limit levels of asbestos in water, and restrict general use of asbestos in products and product packaging. Other agencies involved in the regulation of asbestos include: the Department of Transportation - regarding the transport of asbestos, the National Institute of Standards and Technology - establishing standards and protocols for laboratory accreditation, and the Consumer Product Safety Commission - banning asbestos in some products (E.P.A., 1985, p.L-2). The Federal Food & Drug Administration is also involved in asbestos regulation, by controlling the use of asbestos in drugs and food-packaging materials (A.T.S.D.R., 1990).

While general asbestos regulation is an issue addressed by several different agencies, the regulations governing the sample types in this study are primarily issued by the E.P.A.. The E.P.A. maintains control of ACM in buildings by setting standards for inspection, identification, removal, and enclosure of ACM. These standards govern communications (i.e., notices and signs required for sites with ACM), certified identification methods, extraction and cleaning techniques, documentation, and follow-up site review.

The following quantitative guidelines for asbestos in buildings have been established by the E.P.A.: "Asbestos is present if the material analyzed is more than one percent asbestos by weight...if asbestos is present, then an asbestos control program should be developed" (E.P.A., 1985, p.2-6). Further, the O.S.H.A. maintains a permissible exposure limit (PEL) of 200,000 fibers/m^3 average daily concentration allowed in the workplace. Should asbestos levels in a building exceed these limits, regulatory action is initiated. In addition to these guidelines, buildings undergoing extensive reconstruction or demolition are required to have ACM removed.

However, even some building materials that are found to be ACM by inspection are not required to be removed from the site. In these cases, the type of material (i.e., spray, insulation, ceiling tiles) and its friability are also considered in the risk assessment of ACM in buildings. If the ACM is non-friable, well-contained, or enclosed, and is unlikely to erode into airborne particles, it may be allowed to remain at the site to be maintained by periodic inspection. In fact, removal projects of some ACM create a greater risk of exposure for building inhabitants, as the remediation effort may cause asbestos emission. In these cases, enclosure is favored over asbestos removal.

Guidelines regarding sample procedures, identification techniques, removal and enclosure of ACM, and inspection are discussed in the Guidance for Controlling Asbestos-Containing Materials in Buildings (E.P.A., 1985).

Conclusion

The samples taken from Orton Library were found to contain chrysotile asbestos. The presence of chrysotile was confirmed only by optical microscopy. Neither electron microprobe analysis nor analysis by X-ray diffraction indicated the presence of asbestos. Owing to the treatment of the samples with dilute HCl, no quantitative assessment of relative asbestos percentages in the samples was made. This inability to estimate asbestos percentages further prohibited the classification of the samples as "asbestos-containing material", as defined by the E.P.A. (1985).

While epidemiological studies have established a connection between respiratory diseases and exposure to asbestos minerals, the risk of developing asbestos-related disease through exposure to asbestos in buildings is minimal. The health risks from environmental exposure are extrapolated from studies linking respiratory diseases to occupational exposure in industries such as mining, milling, and shipbuilding. Building inhabitants are not likely to be exposed to the same levels of asbestos fibers that the workers (upon which the studies were based) were. Furthermore, "the presence of asbestos in a building does not mean that the health of building occupants in endangered. If ACM remains in good condition and is unlikely to be disturbed, exposure will be negligable" (E.P.A., 1985, p.1-1). As the samples in Orton Library were taken from an enclosed area, the risk of asbestos emission is improbable. Finally, studies indicate that amphibole asbestos minerals such as crocidolite or anthophyllite cause more harm to the respiratory system than chrysotile. The samples analyzed for this study did not contain amphibole asbestos. The lack of amphibole asbestos also reduces the potential health hazards to occupants of Orton Library.

Again, this study does not attempt to make judgment of the safety of Orton Library. Formal risk assessment must be conducted by an accredited agency, following guidelines established by the E.P.A..

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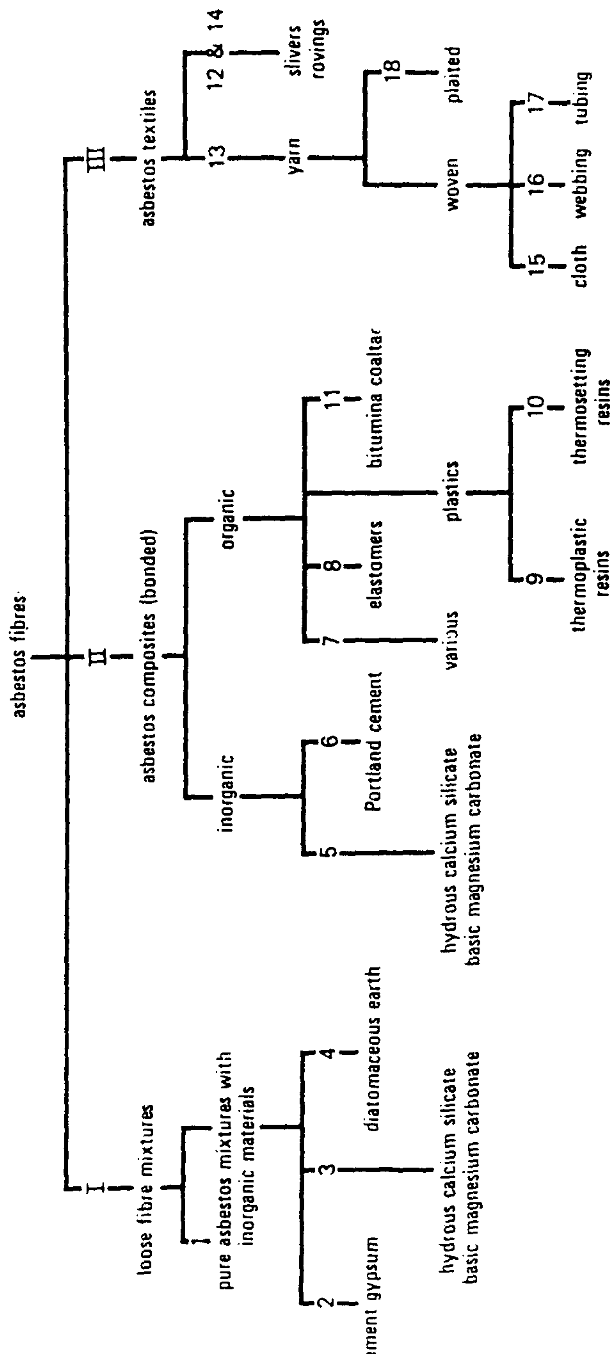
	Chrysotile	Crocidolite	Amosite
Tensile strength , MNm^{-2}	3100	3500	2500
Elastic modulus , GNm^{-2}	160	190	160
Specific gravity	2.55	3.43	3.37
Magnetic susceptibility, mean at 10k Oe	5.3×10^{-6}	78.7×10^{-6}	60.9×10^{-6}
% loss in tensile strength, at			
300°C	0	13	37
400°C	[2.7][3]	63	61
500°C	[13.5][3]	78	80
600°C	84	83	96
% wt loss, boiling refluxed 4M HCl, for			
0.5 h	60	6	8
2 h		7	15
4 h		7.5	22
8 h		8.5	30

Table 1

Comparison of the Diffraction, Optical and Mechanical Properties of the Six Asbestos Minerals

Mineral	Composition (Idealized)	Unit Cell Parameters				Optical Parameters		Tensile Strength	Flexibility
		a (nm)	b (nm)	c (nm)	B (degrees)	n	n_s		
Chrysotile (Canadian)	$Mg_3Si_2O_5(OH)_4$	0.532	0.920	1.464	92.3	1.537–1.554	1.554–1.557	31	good
Actinolite	$Ca_2(Mg,Fe^{+2})_5Si_8O_{22}(OH)_2$	0.989	1.820	0.531	104.63	1.600–1.628	1.625–1.655	<5	fair to brittle
Amosite	$(Fe^{+2},Mg)_7Si_8O_{22}(OH)_2$	0.951	1.830	0.533	101.06	1.670–1.675	1.683–1.694	25	fair
Anthophyllite	$(Mg,Fe^{+2})_7Si_8O_{22}(OH)_2$	1.850	1.790	0.529	90.00	1.578–1.652	1.591–1.676	24	fair to brittle
Crocidolite (Cape Province, S. Africa)	$Na_2(Fe^{+2},Mg)_3Fe_2^{+3}Si_8O_{22}(OH)_2$	0.974	1.806	0.531	103.73	1.682–1.696	1.686–1.700	35	good
Tremolite	$Ca_2Mg_5Si_8O_{22}(OH)_2$	0.987	1.802	0.533	104.65	1.599–1.628	1.591–1.676	<5	brittle

Table 2



asbestos fibres
I
loose fibre mixtures
II
asbestos composites (bonded)
III
asbestos textiles
1
pure asbestos mixtures with inorganic materials
inorganic
organic
2
cement gypsum
3
hydrous calcium silicate basic magnesium carbonate
4
diatomaceous earth
5
hydrous calcium silicate basic magnesium carbonate
6
Portland cement
7
various
8
elastomers
plastics
9
thermoplastic resins
10
thermosetting resins
11
bitumina coaltar
13
yarn
12 & 14
slivers rovings
woven
18
plaited
15
cloth
16
webbing
17
tubing
WHO 85/699

Figure 1

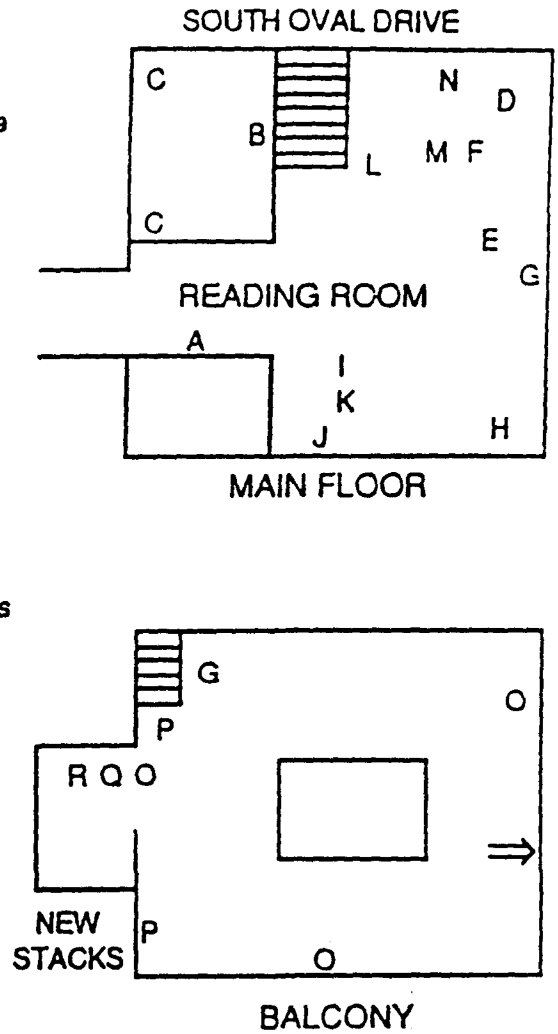
	Approximate asbestos content (% weight)	Asbestos fibre type	Reference to Fig.1
1. Asbestos-cement building products	10 - 15	C, A, Cr	II-6
2. Asbestos-cement pressure, sewage, and drainage pipes	12 - 15	C, Cr, A	II-6
3. Fire-resistant insulation boards	25 - 40	A, C	II-6, II-5
4. Insulation products including spray	12 - 100	A, C, Cr	I-1, I-2, I-3, I-4, II-5
5. Jointings and packings	25 - 85	C, Cr	II-8, III-18
6. Friction materials	15 - 70	C	II-10
7. Textile products not included in (6)	65 - 100	C, Cr	III
8. Floor tiles and sheets	5 - 7.5	C	II-9
9. Moulded plastics and battery boxes	55 - 70	C, Cr	II-9, II-10
10. Fillers and reinforcements and products made thereof (felts, millboard, paper, filter pads for wines and beers, underseals, mastics, adhesives, coatings, etc.	25 - 98	C, Cr	II-7, II-11

C: chrysotile
Cr: crocidolite
A: amosite

Table 3

KEY TO THE FLOOR PLAN

A - Circulation Desk; closed reserve
B - Abstracts and bibliographies
C - Selected new serials and complete sets of four major serials
D - Ohio Corner
E - Ohio maps
F - Indices for periodicals and guidebooks
G - Reference
H - Circulating books
I - Atlases, theses, dissertations
J - Maps - U.S., North America, world, oceans
K - Field trip guidebooks
L - 15 minute U.S. topographic maps
M - Geological Society of America publications
N - U.S. Geological Survey publications
O - Serials
P - State geological survey publications
Q - Oversize books and serials
R - Uncataloged foreign serials
S - Map Room
T - Reprints and vertical file



⇒ - Sample Area

Figure 2

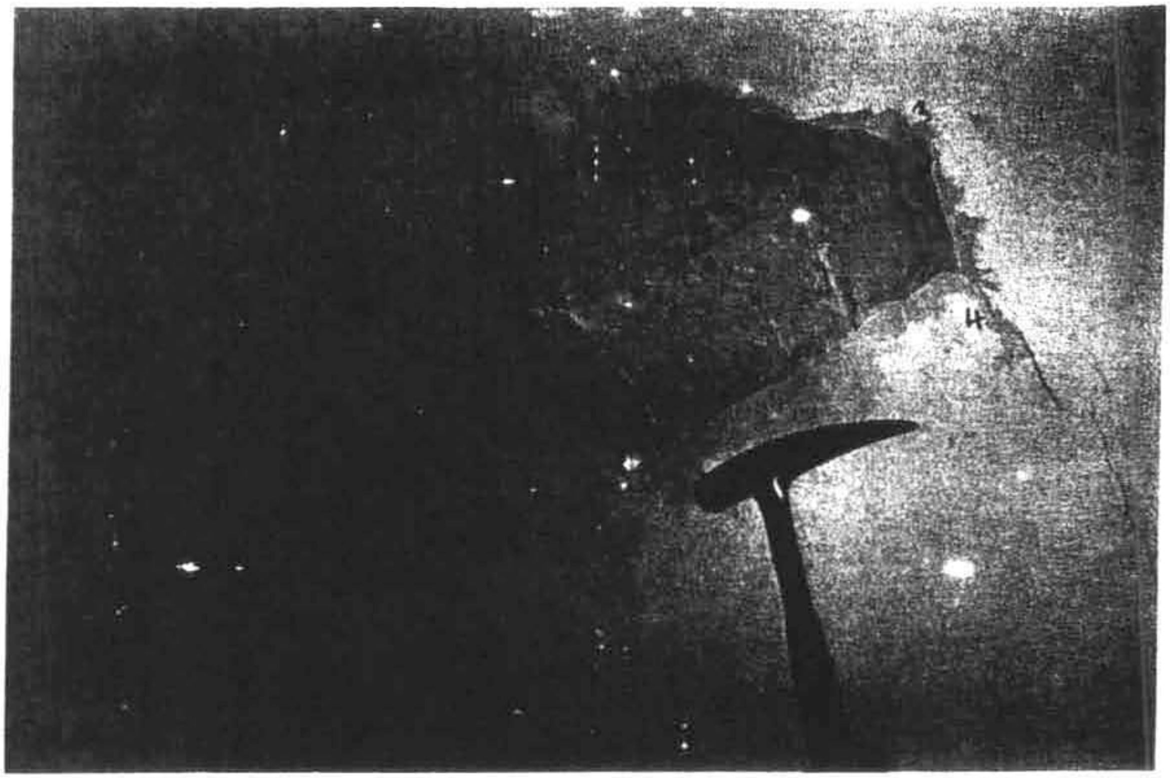


Figure 3

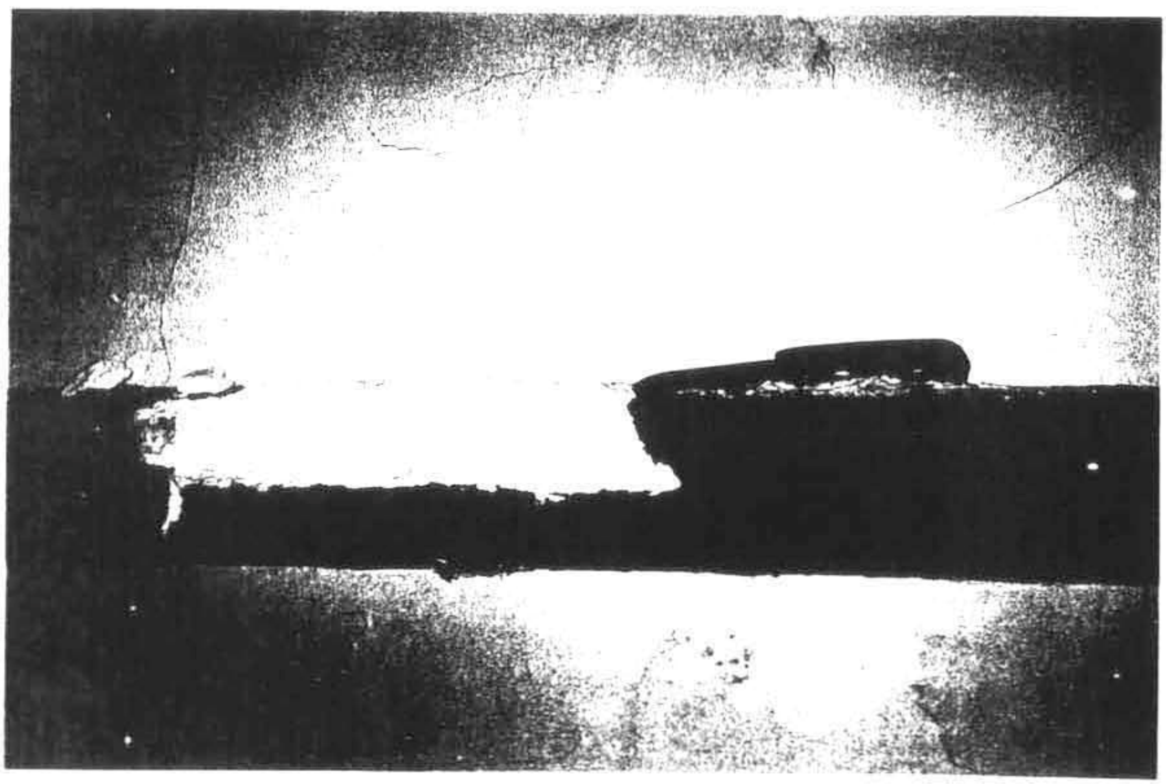
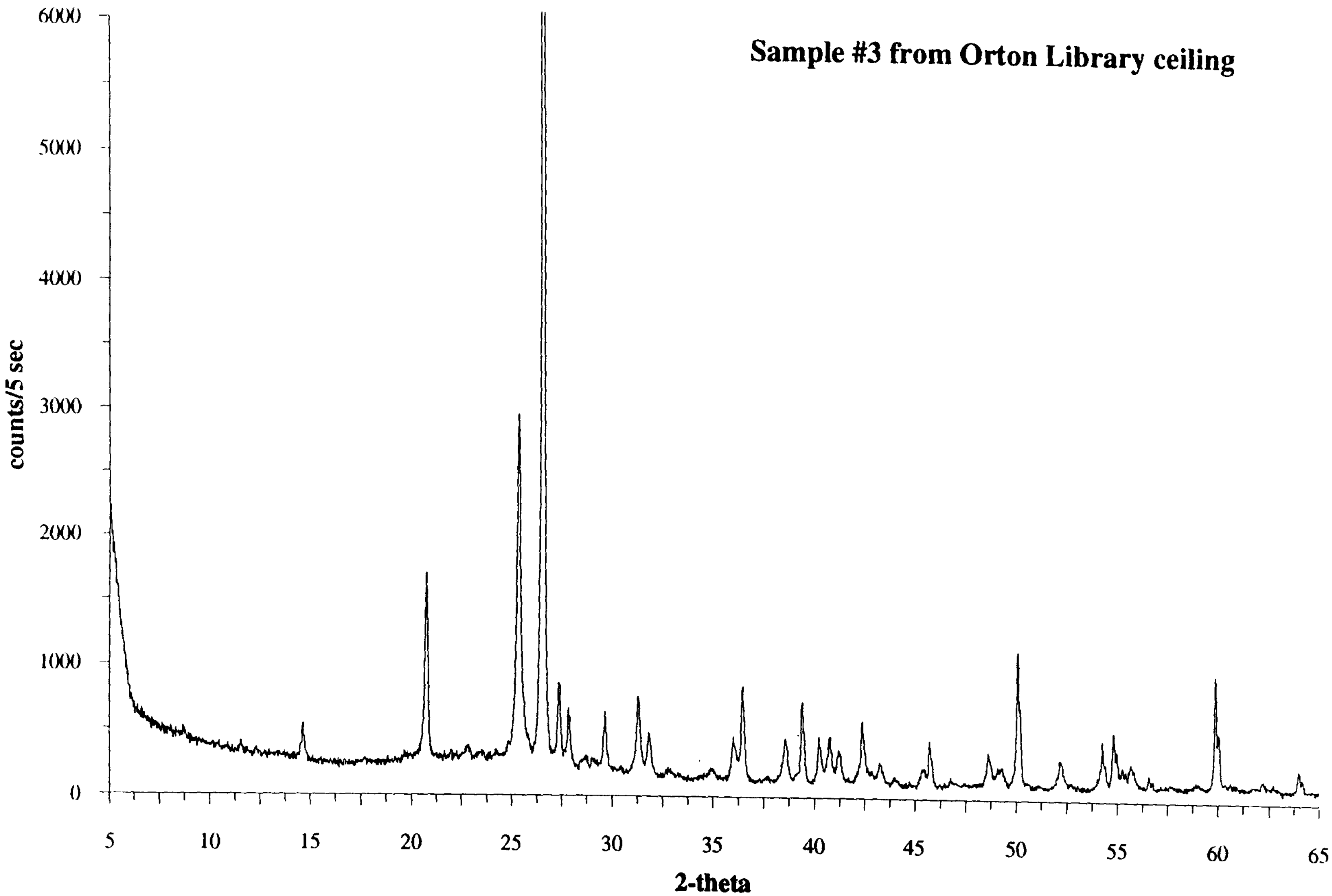


Figure 4



Sample #3 from Orton Library ceiling
counts/5 sec
6000
5000
4000
3000
2000
1000
0
5
10
15
20
25
30
35
40
45
50
55
60
65
2-theta

Figure 5

XRD Pattern Identification for Sample #3

2- theta value	d-spacing value*	Probable mineral
8.8	10.05	Mica
14.75	6.01	Bassanite
17.65	5.02	Mica
19.75	4.5	Mica
20.85	4.26	Quartz
22.85	3.89	Anhydrite
25.45	3.5	Anhydrite, Bassanite(?)
26.6	3.35	Quartz
27.4	3.26	Feldspar
27.9	3.2	Feldspar
28.55	3.13	Anhydrite
29.7	3.01	Bassanite
31.35	2.85	Anhydrite
31.85	2.81	Anhydrite, Bassanite(?)
36.55	2.46	Quartz
38.6	2.33	Anhydrite
39.5	2.28	Quartz
40.3	2.24	Quartz
40.8	2.21	Anhydrite
41.25	2.19	Anhydrite (?)
42.45	2.13	Quartz
43.3	2.09	Anhydrite
45.25	2	Anhydrite (?)
45.8	1.98	Quartz
48.75	1.87	Bassanite, Anhydrite (?)
49.75	1.83	Bassanite (?)
50.15	1.82	Quartz
52.25	1.75	Anhydrite
54.35	1.69	Bassanite (?)
54.9	1.67	Quartz
55.35	1.66	Quartz
55.75	1.65	Anhydrite

* d-values from R.T. Tettenhorst

Table 4.

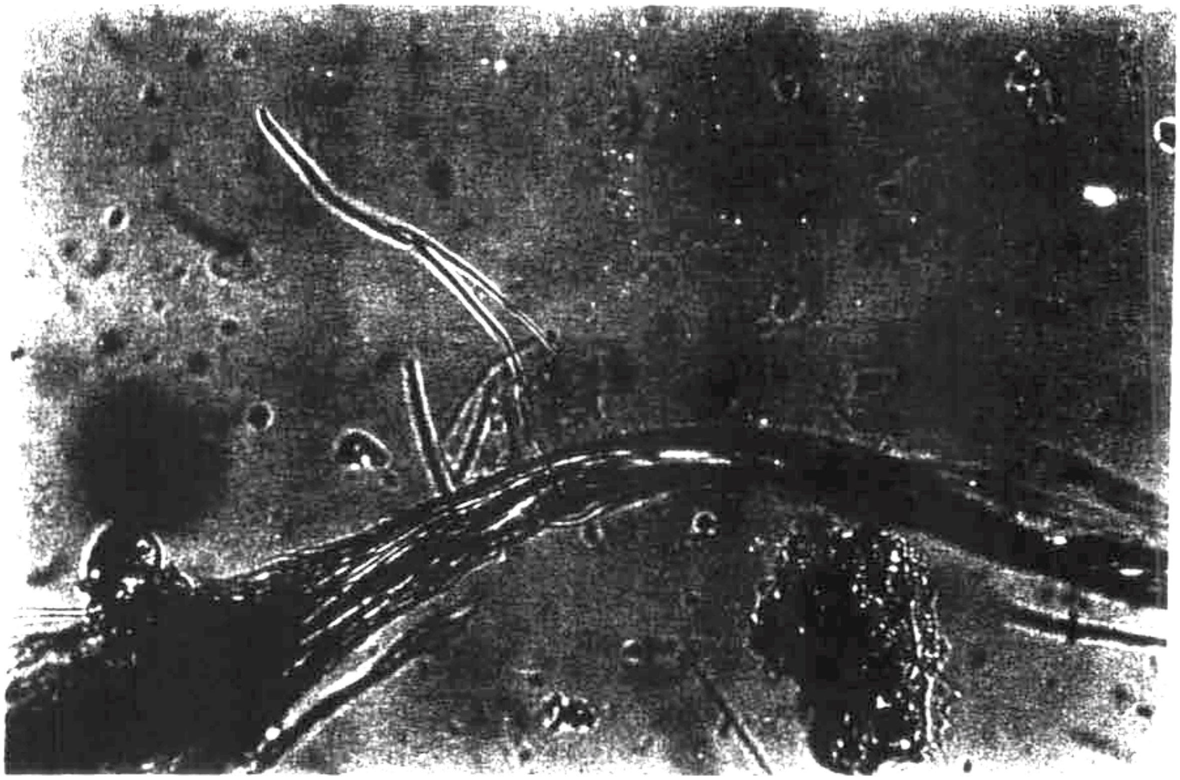


Figure 6

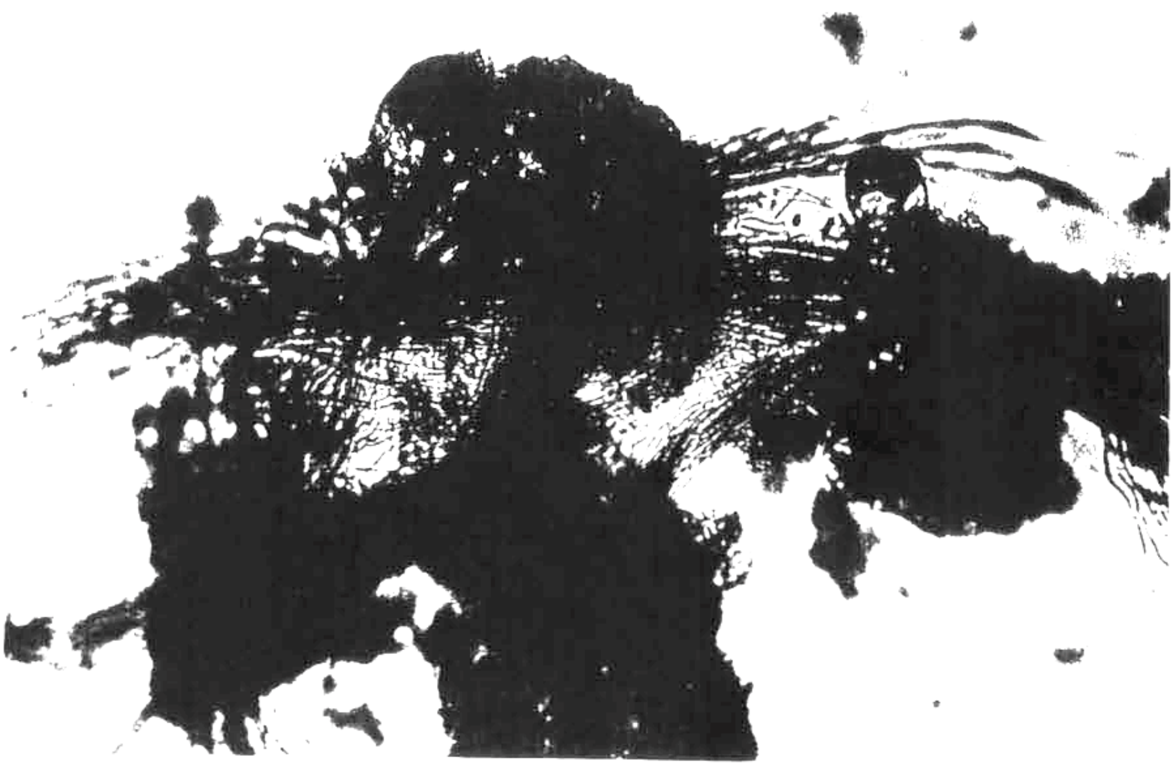


Figure 7

Survey to See If Asbestos Is Present

- Appoint an asbestos program manager and assemble a survey team.
- Check building records for evidence of asbestos- containing surfacing materials, pipe and boiler insulation, or miscellaneous ACM.
- Locate and document all ACM identified in building records.
- Inspect the building for friable materials on walls or ceilings. Inspection means touching walls and ceilings.
- Inspect the building for insulation on pipes and boilers. Inspection means looking at pipes and boilers.
- Be persistent. Friable materials may be hidden behind dropped ceilings or partitions.
- Collect samples of friable ceiling and wall materials following EPA procedures.
- Collect samples of pipe and boiler wrap if the insulation is exposed. Otherwise, assume the insulation contains asbestos.
- Send samples to a qualified laboratory for analysis by polarized light microscopy (PLM). If the samples show more than one percent asbestos, the building contains ACM.
- Document all findings.

Establish a Special Operations and Maintenance (O&M) Program

- Obtain cooperation of building maintenance and custodial managers.
- Educate building occupants and employees about ACM.
- Train custodial and maintenance workers in special cleaning techniques and maintenance precautions.
- Clean the building thoroughly using wet cleaning and HEPA-vacuum techniques.
- Repeat the cleaning monthly (near surfacing materials) or semi-annually (near wrapped insulation).
- Take special precautions before starting maintenance and construction work.
- Inspect ACM at least twice a year for evidence of damage or deterioration.
- Continue the O&M program until all ACM is removed.

Assess the ACM to Determine the Need for Further Action

- Assess the likelihood of fiber release from the ACM by evaluating its current condition and the potential for future disturbance, damage or erosion.
- Determine:
  - The need for further action
  - When it should be done.
  - What abatement method should be used

Conduct Abatement Actions if Needed

- Hire an abatement contractor or, if in-house capabilities are available, use building staff
- To select a contractor:
  - Write precise contract specifications.
  - Check references.
  - Conduct interviews.
  - Review insurance coverage.
  - Select the "best" contractor, not necessarily the lowest bidder
- To Manage the work:
  - Inspect the work site at least four times a day to insure compliance with all prescribed work practices and worker protection measures. These include:
    - Construction of a containment barrier around the entire work area, or the use of containment bags for wrapped insulation.
    - Use of coveralls and respirators by the workers.
    - Provision of worker change and decontamination facilities
  - Stop abatement work immediately if any condition of the worksite appears to be hazardous
  - Release the contractor only after:
    - The work site has been thoroughly cleaned at least twice
    - The work site passes a visual test for abatement completion and cleanliness
    - The work site passes a test for airborne asbestos.

Figure 8